Analysis of Aerofoil Blade using ANSYS for a Vehicle Mounted Micro Wind Turbine

S.N. Prasad, Sai Sashankh Rao and Vijay Mohan

Abstract - **Energy is the primary and most universal measure of all kinds of work by human beings and nature. Everything that happens in the world is an expression of energy in one of its forms. "Energy can neither be created nor be destroyed. It can only be converted from one form into another". So can wind energy be converted from one form to another. Wind energy is readily converted into mechanical energy through the turbine blades and is further converted into electrical energy by connecting the turbine to an electrical generator. In this paper we analyze the aerofoil cross section blade using ANSYS 10.0 and show the velocity profile for a blade which is positioned parallel to the flow of wind and another blade which is tilted at a certain angle to the flow of the wind. This paper also visualizes the use of a variable geometry blade to minimize the drag when the wind flows over the blade.**

Keywords - **Aerofoil blades, Drag, Variable Geometry Blade, Velocity Profile.**

I. INTRODUCTION

Wind energy is one of those forms of energy that is not utilized effectively. Wind turbines are produced specifically for battery charging for the leisure, telecoms and control market [1]. A recent study by the Green Alliance compared the benefits of investing in micro-generation rather than a new round of nuclear power stations, and concludes that micro-generation is a cost-effective, low-carbon alternative to nuclear power [2].

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The increasing popularity of micro wind turbines has also opened up new applications previously considered off-limits to wind energy, such as charging electric fences and powering remote telephone call boxes, once the sole domain of solar cells [3]. Noting the significance of the above points this paper aims at introducing the concept of a vehicle mounted micro wind turbine. The wind energy which flows over a vehicle either a car, train, bus etc. is wasted. This energy can be utilized by implementing small components such as a wind turbine and generator in the vehicle. The radial force acts on the blades and thus the blades attached to the generator starts rotating which drives the generator and thus producing electricity. The investment and implementation of such components into the vehicle would not make a huge difference in the total cost of the vehicle. The rotation of the blades i.e. the mechanical energy is converted into electrical energy. The other components which are necessary in the conversion process are shaft, gear box and mountings. When a vehicle travels through air, the air is forced over it. The velocity of the air may be assumed to be equal to that of the vehicle but in the opposite direction, neglecting wind speed. This kinetic energy of the air which under normal circumstances would be wasted could be utilized effectively to generate power. There are many blades that may be used for the conversion of wind energy into mechanical energy. In this paper we analyze the effects of air flowing over an aerofoil blade variable geometry type when applied to a turbine mounted on a vehicle. The difference in the flow rates of air between the upper and lower surfaces of the blade sets up a pressure difference which results in a reaction force that causes the blades to move. The same is explained pictorially in Figure 1.

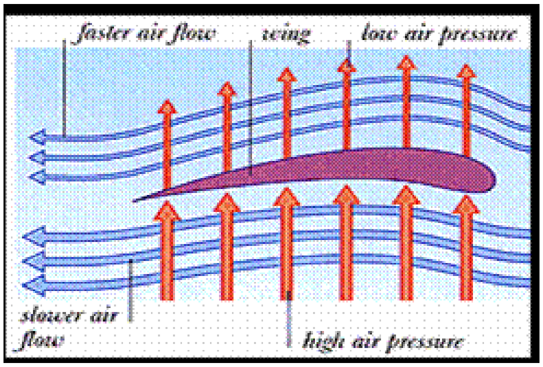

Figure 1: Concept of an Aerofoil.

The use of a variable geometry blade minimizes drag and provides an optimum balance of power generation versus drag. The blade works on the principle of centrifugal force to vary its dimensions. A model of the aerofoil cross section blade has been created using the Unigraphics Software, UGNX4 as shown in Figure 2. The model has been created to vary from a diameter of 3cm to 10cm.

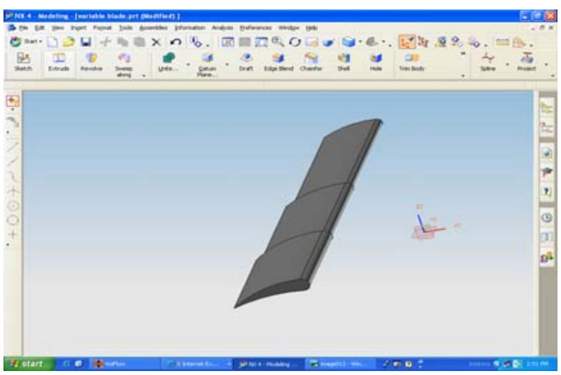

Figure 2: CAD model of a variable geometry Blade using UG NX4.

II. ANALYSIS OF AEROFOIL BLADE

Using the Viziflow software the aerofoil blades were subjected to an air flow analysis at an air flow rate of 13.31mph (5.95m/s) and at atmospheric pressure. Figure 3 and Figure 4 show the change in streamlines across the aerofoil when it is placed horizontal and when it is kept at an angle of 15 degrees to the horizontal respectively.

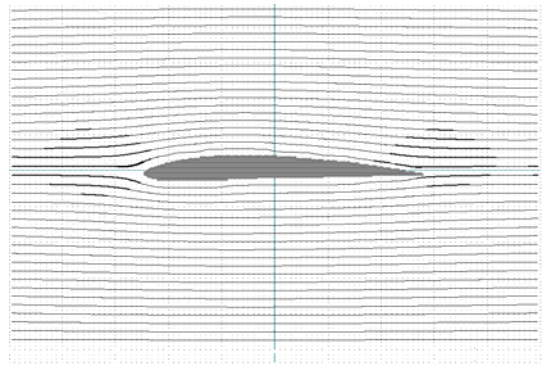

Figure 3: Streamlines over a horizontal aerofoil.

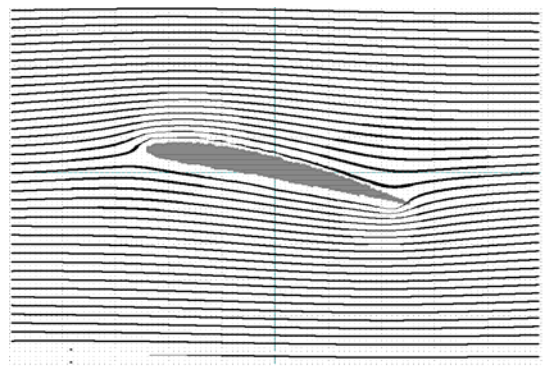

Figure 4: Streamlines over an aerofoil inclined at 15 degrees to the horizontal.

Ansys10.0 has been used to further analyze the velocity profile across aerofoil blades. The boundary conditions that were fixed are: Incoming air stream at 13.31mph, velocity at the surfaces of the aerofoil equal to zero (from the boundary layer concept) and constant pressure on the remaining three sides of the control volume. This is indicated in Figure 5 [4, 5]. A vehicle speed of 13.31mph (21.42km/h) has been chosen assuming a high traffic density scenario.

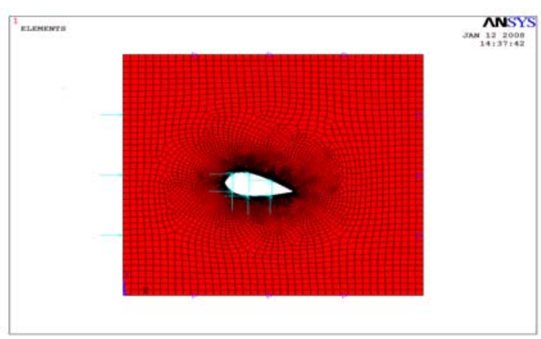

Figure 5: Boundary Conditions.

The velocity profile for aerofoil blades placed horizontal to the wind flow and tilted at an angle of 15 degrees to the horizontal are shown in Figure 6 and Figure 7 respectively.

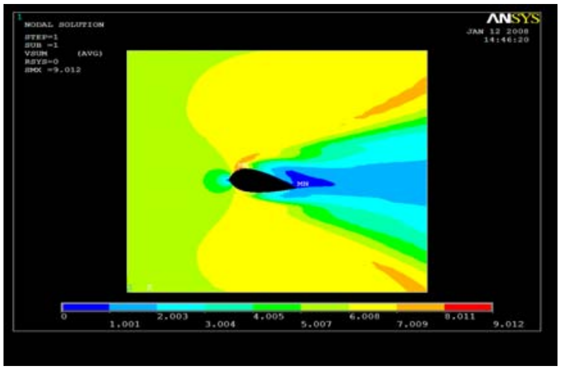

Figure 6: Velocity Profile of air flow over a horizontal aerofoil.

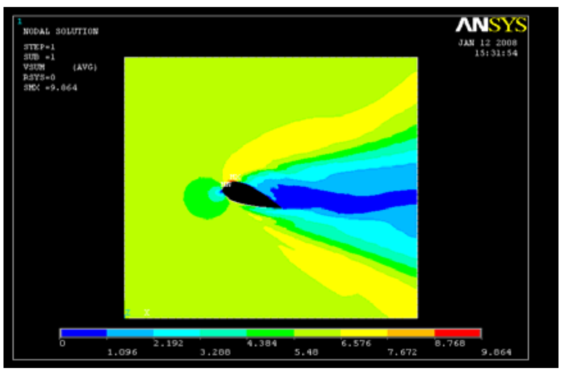

Figure 7: Velocity Profile of air flow over an aerofoil inclined at 15 degrees to the horizontal.

Table I: Nodal Solution obtained from ANSYS.

	Blade Horizontal	Blade Tilted
Nodal Solution (SMX)	9.012	9.864

The Vector plots for the above same blades are also shown in Figure 8 and Figure 9.

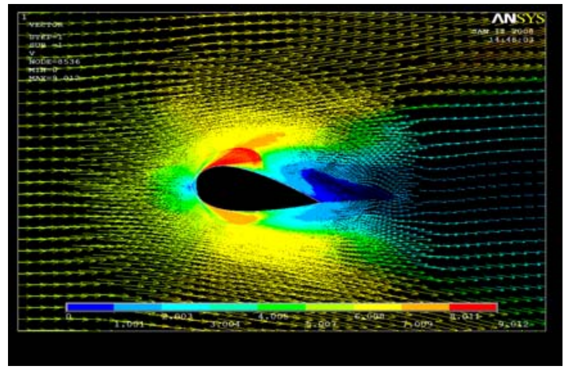

Figure 8: Vector Plot of air flow over a horizontal aerofoil.

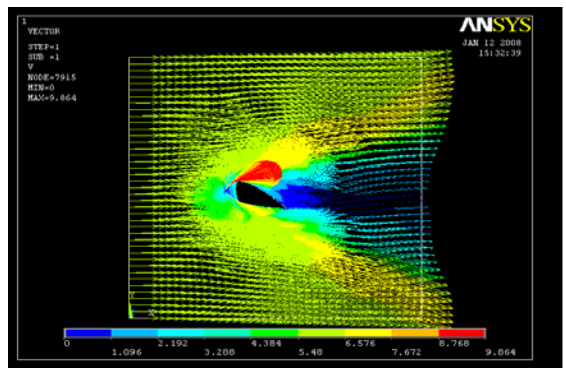

Figure 9: Vector Plot of air flow over an aerofoil inclined at 15 degrees to the horizontal.

It can be observed that when the aerofoil is placed at an angle, the difference between the velocities of air on the top and bottom surfaces is significantly greater when compared to it being placed horizontally. In Figure 7 the yellow region is more predominant on the top surface than the bottom surface suggesting higher flow differential as compared to that in Figure 6. This results in a greater pressure difference and hence more force for movement of the blade.

III. POWER GENERATION

The power generated by the micro turbine is due to the differential pressure acting on the surfaces of the aerofoil blade. This causes a torque which results in rotational movement of the rotor [6]. The total power available from the kinetic energy of the air is given by the following calculations:

The diameter of the turbine is taken as 10cm for our application and the air speed is 13.31mph i.e. 5.95m/s.

Total Power, $W = (\rho A V^3)/2$ Watts-------------- (a)

Where,

ρ is the air density in kg/m^3,

V is the air velocity in m/s,

A is the area (in m^2) of the turbine = $(\pi D^2)/4$

D is the turbine diameter in m

$\rho = P/(RT)$-- (b)

Where,

P is the pressure of air in N/m^2,

R is the Universal Gas Constant in kJ/kg-K,

T is the absolute temperature in K (293),

R = 0.287kJ/kg-K and P=1.0132e5 N/m^2,

ρ = (1.01325e5)/ (287*293) = **1.205 kg/m³**

Therefore, $W = (1.205*0.00785*5.95^3)/(2)$

W = **0.996 W ~ 1 Watt**

Thus we can observe that for a velocity of 5.95m/s, which can be easily achieved by a vehicle, a power equal to 1 Watt can be generated. This is the minimum requirement for charging a mobile. Further this concept can be implemented for velocities of more than 5.95m/s to produce a power of more than 1 Watt which can be used for other applications.

IV. CONCLUSION

The analysis of the aerofoil wind turbine blade and the power available in the air at 13.31mph suggests that it is extremely possible to use the wind energy generated by the movement of a vehicle to generate sufficient power to run a mobile phone and with increase in velocity more power can be produced for other purposes. The analysis suggests that an inclined aerofoil blade would be more efficient in the energy transformation. Appropriate lightweight material must be used for the construction of the variable geometry blade to make it sensitive to speed change. The energy generated at this low speed of 5.95 m/s clearly provides insight into the potential of wind energy.

ACKNOWLEDGMENT

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